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CONTRACTOR REPORT ARLCD-CR-82021

**MANUFACTURING PROCESSES FOR VARIOUS
SHAPED CONSUMABLE ORDNANCE PRODUCTS**

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**US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
LARGE CALIBER
WEAPON SYSTEMS LABORATORY
DOVER, NEW JERSEY**

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)		
<p>The work covered by this report consisted of the manufacture of a variety of different shaped combustible ordnance products. Matched metal molding and spiral wrapping processes were utilized with five different product formulations. Some difficulty was encountered in preparing small batches which indicates a relationship between composition, batch, and equipment size. Unforeseen shrinkage factors, apparently due to the unusual shape of sleeves, caused minor distortion between inside and outside diameters. Talc was successfully incorporated</p> <p style="text-align: right;">(cont)</p>		

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20. ABSTRACT (cont)

into the formula and product for the first time, with the only significant difference being a slightly higher product off-press weight and slick feeling of the product's outer surface. The process of spiral wrapping with nitro-cellulose paper was successful in producing chemically and dimensionally acceptable product.

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INTRODUCTION

This contract, with its subsequent modification, required the investigation into, and manufacture of, a number of consumable casings and components by the molded fiber process and spiral wrapping process, in order that the government could evaluate the use of consumable structures in their then-current experiments.

The contract scope of work with modifications consisted of five separate tasks involving four different rounds and requiring nine different sets of tools (eight being designed and fabricated for the contract), five different product formulations, and two basic processes (molding and spiral wrapping). The spiral wrapping of nitrocellulose (NC) papers was completely new to the company. The time frame was November 1977 to October 1980.

The tasks were broken down into three groups:

1. Task 1 and task 3 - 60-mm case
2. Task 6 - sleeve
3. Task 7 and task 8 - rigid bag charge

Tasks 2, 4, and 5 were deleted from scope of work by amendment of contract.

PROCESS OF MANUFACTURE

Process Description

The current state-of-the-art for the molding of high density consumable ordnance items evolved from various slurry preform and pressing techniques that were employed during the past century in the manufacture of three dimensional shapes from wood cellulose fibers. Basically it is a commercial art for making hollow wares of a paperboard-type composition.

The present, controlled concept employed by Armtec in making high-density, consumable ordnance items is described in the following sections. The method described was employed to manufacture the spacer and sleeves applicable to this report (fig. 1).

Batch Preparation

1. A hydropulper is filled with a predetermined amount of water.
2. A specified amount of acrylic fibers is added (previously fibrillated).

1. KRAFT
2. NC
3. ACRYLIC FIBER
4. DPA
5. RESIN EMULSION

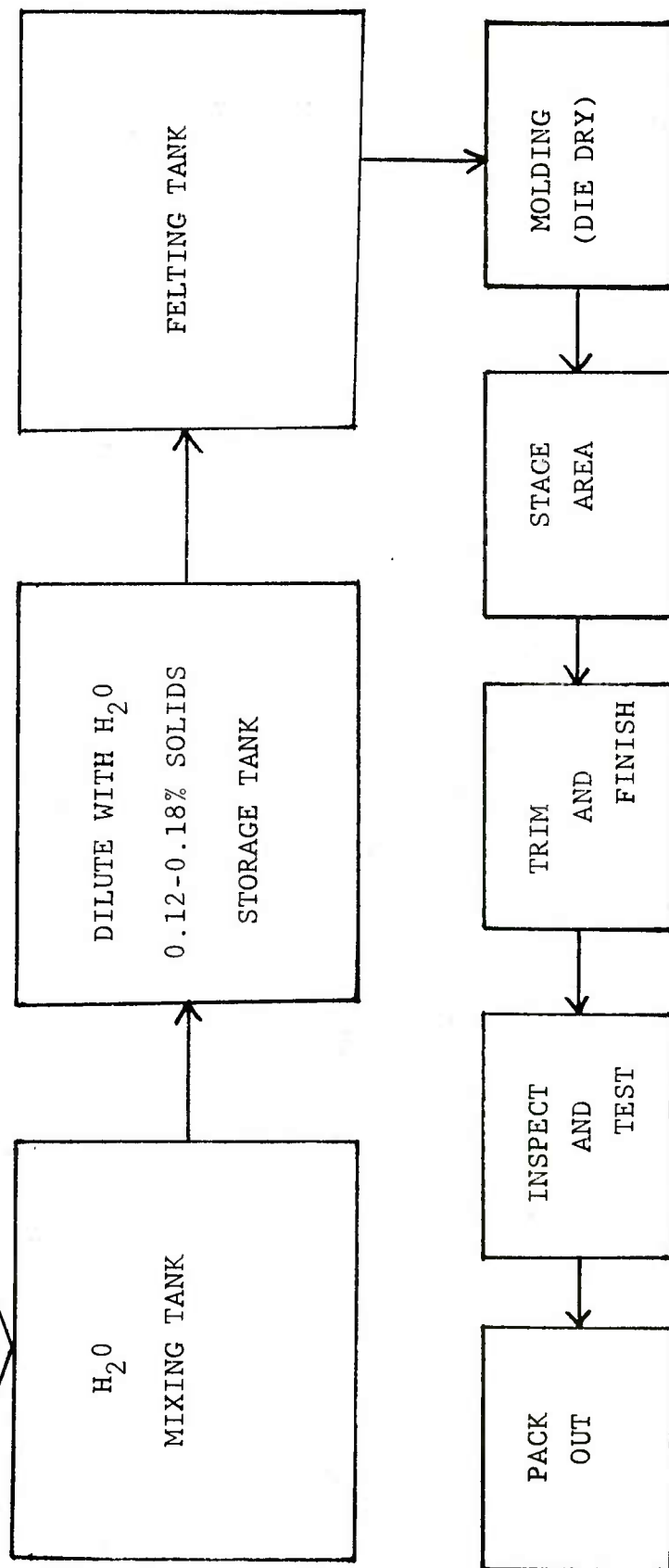


Figure 1. Schematic of consumable case production

3. The mixture is beaten until the desired freeness is attained.
4. The contents are then pumped to a mixing tank.
5. The hydropulper is again filled with the proper amount of water.
6. A specific amount of Kraft fibers is added to the water.
7. The mixture is beaten until the desired freeness is attained.
8. A measured amount of nitrocellulose fibers is then added.
9. The entire batch is agitated for a few seconds until a homogeneous mix is obtained.
10. The homogeneous mixture is added to the mixing tank.
11. Resin is added within the mixing tank by employing the various prescribed steps that will obtain complete precipitation of the resin upon the fibers.
12. The batch is then pumped to a large intermediate tank, and sufficient water is added to reduce the slurry consistency to approximately 0.15% solids.
13. The batch is then allowed to stand under constant agitation for a minimum of one hour.
14. The slurry mix or batch is then pumped to a final supply tank where the mixture is kept in suspension by constant agitation, ready for use.
15. The slurry is pumped from the supply tank to the felting tank on a continuous basis. The slurry mixture is kept in constant agitation by mechanical methods.

Felting

Preforms are made in the felting tank by vacuum accretion of the fibers onto a perforated and screened shape (felting die) having exterior dimensions comparable to the configuration of the open sleeve. The perforated shape is affixed to a manifold, which is connected to a vacuum source.

The felting die is immersed mechanically into the felting tank, and a vacuum force is applied. The length of immersion time plus the rate of the vacuum source dictates the amount of build up of fibers around the exterior wall of the preform die. This, in turn, controls the weight of the preform.

When the preform, or felt, is removed from the felting die, it is a soggy, loosely woven matrix (approximately 60% water) with a wall thickness 3 1/2 times greater than the finished part to be molded.

The felting tank is rectangular. The slurry input is from the bottom center with a rectangular baffle, mounted to give a 1/4-inch opening or slot between the baffle and the tank bottom, thus diffusing an equal amount of slurry in all directions. The felting tank is allowed to overflow equally over a weir and into a return trough on all four sides. This is designed to give the best possible distribution of the slurry mixture within the felting tank.

Molding

The wet felt is dewatered and cured by a predetermined molding cycle in the steam-heated (350°F) matched metal dies. The male section of the die contains vertical grooves closely spaced on the die face. These grooves are connected to a manifold at the base of the male die. The manifold is connected to the vacuum source.

Dewatering is effected in two steps. First, the free water is literally squeezed out through the vacuum grooves during the die-closing operation. The remaining moisture is then vaporized by the die heat and is vented through the vacuum grooves.

The resin is cured during the closed-die cycle (which is approximately 3 1/2 minutes). The dried part is ejected from the male face by compressed air via the vacuum manifold and grooves.

Spiral Wrapping

Standard commercial papermaking equipment is used to manufacture NC paper rolls of the required formula. The rolls of NC paper are placed on a commercial spiral core-winding machine which is capable of producing tubing in a variety of diameters, lengths, and laminates. Shaped parts for tubes (bodies and rings) of appropriate sizes can then be produced. The one drawback to this process is its limitations to tubular components.

CONTRACT PERFORMANCE

Tasks 1 and 3

Tasks 1 and 3 called for fabrication and delivery of case side-walls in accordance with drawing 9321369, mod 4 (fig. 2) using a variety of compositions (table 1).

The compositions were variations of a previously used formula with the exception of the formula for task 3d, which added talc in lieu of acrylic. This new formulation was attempted since it was thought that the talc had the potential for reducing wear and erosion of gun tables.

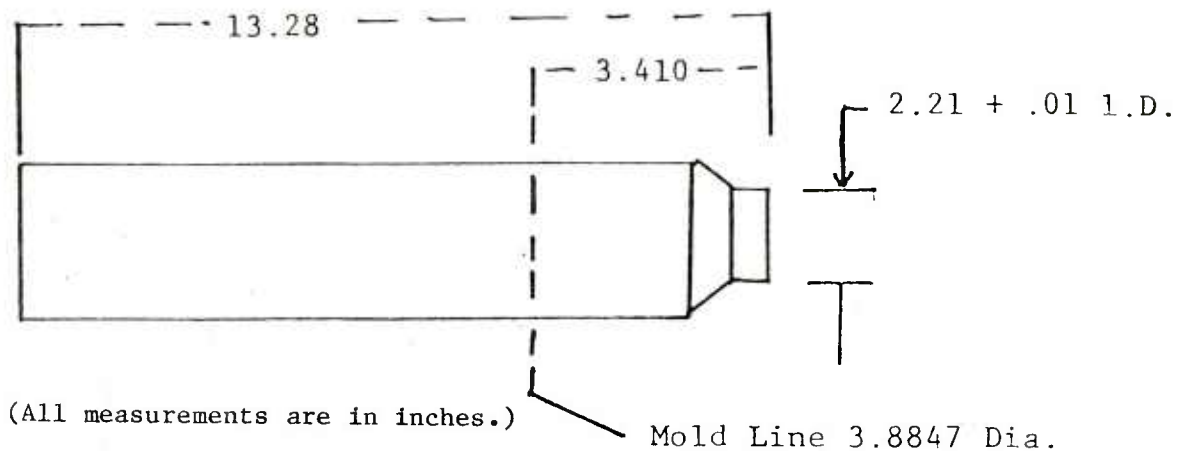


Figure 2. Case sidewall

No difficulties were encountered in the manufacture of the 100 units for task 1 or the 25 units for task 3a. However, when small batches were prepared for the 25 units required for tasks 3b and 3c, the small batches provided inadequate furnish at the required consistency. This problem was corrected with larger batches, allowing manufacture to proceed in a normal manner. This led to the conclusion that there is a relationship between composition and batch/equipment size.

Task 3d required an untried formula introducing talc ($\text{Mg}_3\text{Si}_4\text{O}_{11} \cdot \text{H}_2\text{O}$) to the production at 10% parts-by-weight (pbw) ratio. Although talc has been used in small quantities in paper-making for years, the changes for precipitating the required quantity to the fibers in a furnish batch were considered slim.

However, since the polyvinylacetate-type resin used in the formula is readily precipitable onto the involved fibers, it was believed that the resin particles could be used as a vehicle to carry the fine (1.5 micron) particles of the talc to the fiber and "lake" them, similar to the method used to hold pigments on fibers in some drying processes. As a result, a formula was developed to incorporate the talc into the furnish. Felting and molding of product showed no difficulties. Expected loss of talc to white water was not evidenced.

The only significant differences were: heavier product off-press weight due to the high specific gravity (2.6 to 2.8 gm/cm³) of talc as compared to the combined other materials; and the slick, oily feeling of the product's outer surface. Empirically, and by subtraction of the chemical analysis, it was determined that the talc was retained in the parts.

Process details are shown in table 2 and test results in table 3. Parts meeting all contractual requirements for tasks 1 and 3 were successfully manufactured and shipped.

Task 6

Task 6 called for the design and fabrication of tooling for the fabrication of components molded in an open position and configured to allow for an overlap alignment. Task 6 also required investigation of various methods of permanent attachment of the overlap, specifically mechanical, adhesive bond, stitching and lacing, and acetone weld of sleeves to drawings 9327007-2 (fig. 3).

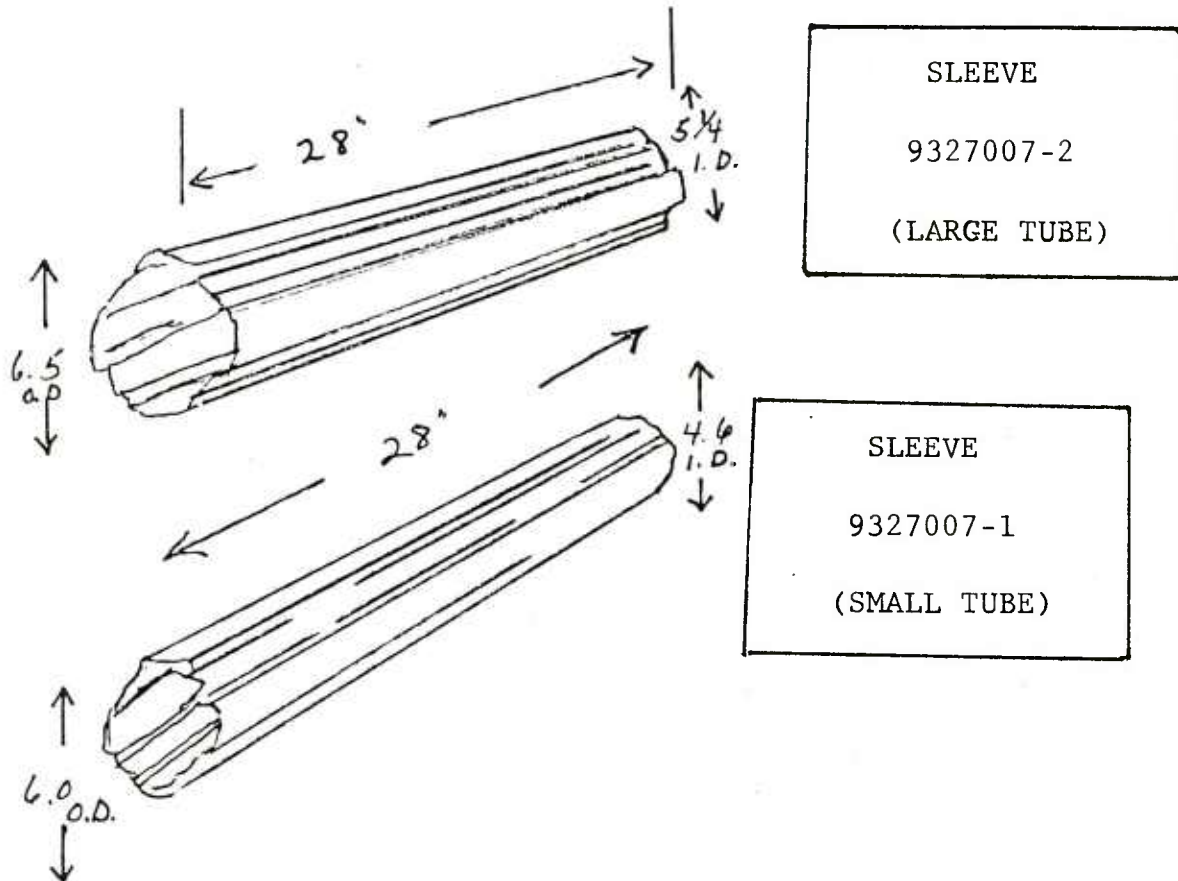


Figure 3. Sleeve

Tooling design and fabrication were initiated. Tools were available in August 1978, but rework and modification delayed production of the first units until February 1979. Product was molded in an open, semi-formed position with the basic inside diameter being post-formed by a specially designed restrike tool to establish proper wet-felted and dry-molded weights to insure that parts produced met specification requirements.

Several methods of joining the tubes together at the lap joint were investigated. Trials at tube assembly with lacing through prepunched holes at lap joint area, bonding, stitching, and gluing were made. The best method was the bonding of the tubes at the lap joint with an acetone bond. Resulting product showed

minimum distortion with no cracks at the joint (product itself delaminated prior to failure of the bond during tests).

Initial dimensional inspection of the finished sleeves revealed minor distortion of finished units involving the relationship between the inside and outside diameters of the finished product, apparently caused by unforeseen shrinkage factors in the forming and re-forming of the unusually shaped product.

Since major design and tooling modification would have been required to correct the problem, the ARRADCOM project officer was notified and work continued. Details of composition, process, and test results are shown on tables 1, 2, and 3.

Task 7

Task 7 was the design and fabrication of tooling for and the manufacture of a number of components for the 155-mm howitzer. Composition is shown in table 1. The parts were to be manufactured to a good fit upon assembly to insure that the preferred method of permanent attachment, a solvent weld, could be employed. Other methods of attachment could be investigated as long as good adhesion and residue-free burning were accomplished.

Unique to the tooling design was the use of standard polyvinyl chloride pipe and pipe fittings in the fabrication of the felting tools. This made the tooling easier to fabricate and in some cases, interchangeable.

In addition, instead of molding all parts, it was decided to attempt to fabricate the body and ring by the spiral wrapping process. This had not been done before.

The spiral core-winding machine was procured from the Paper Converting Machine Company, Green Bay, Wisconsin. This machine, a model 6084 is equipped with dual adhesive application tables, multiple winding heads, and an automatic saw cut-off, and is capable of producing tubing in a variety of diameters, lengths, and laminates (fig. 4).

A winding mandrel for the machine of a diameter equivalent to the inside diameter of the body and ring component was procured with the machine.

A strip (ribbon) or a number of strips of prerolled paper are belt-fed through an adhesive-filled tray; excess adhesive is doctored off of strip surface and fed on a bias to the pickup for a revolving mandrel where it is spirally wound under slight tension with matching seam to form a tube. Successive strips are fed at the same time, with each successive strip being wound over the seam of the preceding winding, forming a laminate. Thickness and other physical characteristics of the finished tube are controlled by the thickness and weight of the paper strip, the number of strips (laminates) used, winding tension, and type of adhesive. The length of each tube is controlled by a micro-switch activated cutoff saw, which moves into the outside of the tube being formed by the machine on the mandrel and trims tube to predetermined lengths.

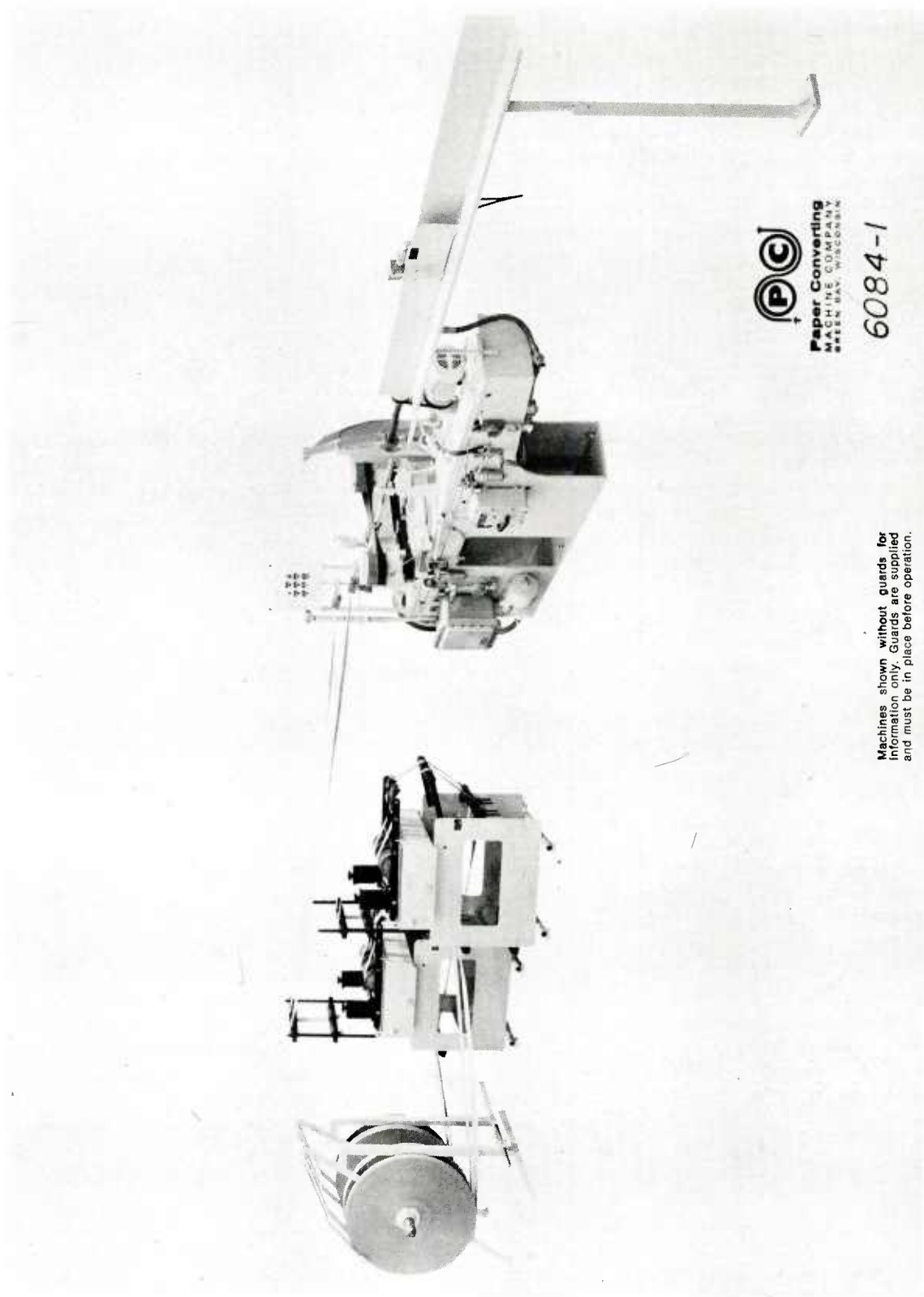


Figure 4. Spiral core-winding machine

Since the body and ring components required the same composition as the other molded components in the assembly, an arrangement was made with Herty Foundation, Savannah, Georgia to manufacture an NC paper to Armtec's formulation (DW69247366), roll it, and split the rolls to widths which could be handled by the wrapping machine (3.90 to 4.00 in.). Initial setup and trial of the core-winding machine using available non-NC paper indicated this width is being optimum for the mandrel. The paper was 0.025 inch thick. On receipt of the rolls of paper, a series of wrapping trials were conducted using several different adhesives developed by National Starch Company, an affiliate of Armtec, who worked on several trial methods of wrapping.

Wrapping trials included two-, three-, four-, and five-ply applications at several different machine settings and feed biases. The adhesives, all of the polyvinyl type, had different wetting characteristics, since this appeared to be the source of the adhesion problem which occurred.

The best results were obtained using a four-ply winding in conjunction with National Starch "Crusader 24" (trade name), with the first ply being applied to mandrel dry, second and third plys coated with the adhesive, and final wrap ply dry.

A sufficient amount of tubing was manufactured in this manner to supply material for fabricating the required number of bodies and rings. The rings were permanently bonded to the bodies by acetone weld. Unfortunately, the resulting assemblies were not rigid enough to perform as intended. The part density was low, probably as a result of Armtec's inexperience with the wrapping machine. As a result, by direction of the ARRADCOM project officer, the units were impregnated with a two component, polyurethane-type resin made by the Bostik Company, Los Angeles and were cured prior to inspection.

Molded components were produced by the standard felting and molding procedure.

Process results are shown in table 2 and testing results in table 3.

Task 8

Task 8 called for use of tooling fabricated in task 7 to manufacture the base cap 9329641 and base charge container 9329642, using a nominal composition of 4.1 NC to inert fibers. Composition is shown in table 1, process in table 2 and test results in table 3. The parts were manufactured using standard felting and molding procedures. No problems were encountered.

CONCLUSIONS

1. There is a correlation between batch composition and batch size in relation to size of equipment. This was evidenced by the problems encountered in small batch sizes of low NC composition in obtaining proper furnish.

2. It is possible to mix talc with the paper. If firing test results prove successful, this could lead to longer tube life. Additional research is warranted.

3. Spiral wrapping is a feasible alternative to molding of tubular components. However, the low density of the material affects rigidity so additional strengthening is necessary. Additional research is warranted to determine proper feed and wrapping speeds, adhesives, and strengthening materials.

Table 1. Chemical composition summary

		Nitro cellulose (%)	Diphenyl- amine (%)	Resin (%)	Kraft (%)	Acrylic (%)
Task 1 P/N 9321369	Required Test	55.0 ± 2.0 55.33	1.0 ± 0.3 .98	10.0 ± 2.0 (KRAD 18.73)*	9.0 ± 2.0	25.0 ± 2.0 24.96
Task 3a P/N 9321369	Required Test	55.0 ± 2.0 52.53	1.0 ± 0.3 1.05	10.0 ± 2.0 (KRAD 20.08)*	9.0 ± 2.0	25.0 ± 2.0 26.34
Task 3b P/N 9321369	Required Test	40 ± 2.0 41.04	1.0 ± 0.3 1.02	10.0 ± 2.0 (KRAD 21.31)*	13.0 ± 2.0	36.0 ± 2.0 36.63
Task 3c P/N 9321369	Required Test	25.0 ± 2.0 26.44	1.0 ± 0.3 1.01	10.0 ± 2.0 (KRAD 26.18)*	17.5 ± 2.0	46.5 ± 2.0 46.37
Task 3d P/N 9321369	Required Test	50.0 ± 2.0 49.32	1.0 ± 0.3 0.74	14 ± 2.0 (KRAD 49.74)*	25.0 ± 2.0	10. Talc
Task 6 P/N 9327007-1 P/N 9327007-2	Required Test Required Test	55.0 ± 2.0 53.97 55.0 ± 2.0 55.93	1.0 ± 0.3 0.94 1.0 ± 0.3 0.93	10.0 ± 2.0 (KRAD 19.11)* 10.0 ± 2.0 (KRAD 19.77)*	9.0 ± 2.0 9.0 ± 2.0	25.0 ± 2.0 25.98 25.0 ± 2.0 23.37
Task 7 All units P/N 9329644 9329639 9329641 9329740 9329638 9329643 9329642	Required Test Test Test Test Test Test Test	55.0 ± 2.0 53.87 53.87 53.83 54.11 53.92 54.10 54.01	1.0 ± 0.3 0.80 0.80 0.94 0.99 0.96 0.93 0.95	10.0 ± 2.0 (KRAD 20.34)* (KRAD 20.34)* (KRAD 19.39)* (KRAD 18.78)* (KRAD 19.24)* (KRAD 19.14)* (KRAD 19.09)*	9.0 ± 2.0	25.0 ± 2.0 24.79 24.79 25.84 26.12 25.90 25.84 25.96
Task 8 All units P/N 9329641 9329642	Required Test Test	72.0 ± 2.0 72.75 73.31	1.0 ± 0.3 0.86 0.72	10.0 ± 2.0 (KRAD 26.39)* (KRAD 25.97)*	17.0 ± 2.0	-0- -0- -0-

*KRAD equals 100% minus the analytical values of nitrocellulose + acrylic + diphenylamine.

Table 2. Felting and Molding Summary

Task	Felt. tank	Felt. tool	Form-ula	Cons. (%)	Felt vac. (Hg)	Felt cyc (sec)	Blow off (psi)	Press	Ram (psi)	Mold dies	Die temp (°F)	Die vac (Hg)	Dry cyc (min)	Blow off (psi)
Task 1 P/N 9321369	P. PLT.	5000104	205-1	0.124	25	50	70	P. PLT.	900	5000102	240	24	4.2	50
Task 3a P/N 9321369	P. PLT.	5000104 3a		0.130	25	50	70	P. PLT.	900	5000102	240	24	4.2	50
Task 3b P/N 9321369	P. PLT.	5000104 3b		0.127	25	50	70	P. PLT.	900	5000102	240	24	4.2	50
Task 3c P/N 9321369	P. PLT.	5000104 3c		0.177	25	50	70	P. PLT.	900	5000102	240	24	4.0	50
Task 3d P/N 9321369	P. PLT.	5000104 3d		0.120	25	50	70	P. PLT.	900	5000102	240	24	4.5	50
Task 6 P/N 9327007-1 9327007-2	P. PLT. P. PLT.	133-1 133-1	205-1 205-1	0.159 0.162	23 23	58 55	0 0	P. PLT. P. PLT.	1000 1000	133(2sh) 133(2sh)	235 240	23 23	4.7 4.7	75 75
Task 7 P/N 9329641 9329640 9329638 9329643 9329642	#2 P. PLT. #2 #2 #2	142(sh9) 500040C 142(sh6) 142(sh8) 142(sh7)	205-1 205-1 205-1 205-1 205-1	0.170 0.170 0.175 0.165 0.170	15 23 25 25 25	46 120 34 40 36	40 25 40 40 40	#10 P. PLT. #10 #10 #10	900 900 900 900 900	142(sh3) 500040 142(sh2) 142(sh3) 142(sh4)	240 235 235 235 235	23 0 23 23 23	4.0 1.75 3.0 3.4 3.5	45 0 45 45 45
Task 8 P/N 9329641 9329642	#2 #2	142(sh9) 142(sh7)	8 spec 8 spec	0.147 0.147	25 25	46 36	40 40	#10 #10	900 900	142(sh3) 142(sh4)	235 235	23 23	4.0 3.5	45 45

Table 3. Physical Testing Summary

	Density	Stability	Tensile	Weight	No. Samples ^a
Task 1 P/N 9321369	0.857-0.885	OK	3606-3688	242-256	2
Task 3a P/N 9321369	0.768-0.781	OK	2460-2810	242-256	2
Task 3B P/N 9321369	0.801-0.865	OK	3347-3852	240-258	4
Task 3c P/N 9321369	0.765-0.773	OK	3178-3621	236-250	2
Task 3d P/N 9321369	0.868-0.806	OK	3640-5932	245-276	4
Task 6 P/N 9327007-1	0.815-0.968	OK	3226-4578	537-768	5
9327007-2	0.834-0.960	OK	3632-4286	609-882	5
Task 7 P/N 9329644 ^b	0.515-0.552	OK	N/A	600-638	5
9329639 ^c	0.515-0.552	OK	N/A	25-28	
9329641	0.815-0.836	OK	N/A	51-56	2
9329640	0.780-0.787	OK	N/A	145-149	2
9329638	0.798 info.	OK	N/A	34-38	
9329643	0.808-0.840	OK	N/A	55.1-57.1	2
9329642	0.815-0.880	OK	N/A	30-34	2
Task 8 P/N 9329641	0.767-0.798	OK	N/A	51-56	2
9329642	0.577-0.698	OK	N/A	30-34	2

a Refers to parts used for test specimens for density, stability and tensile test. Weights were measured 100%.

b Spiral wrapped body

c Spiral wrapped body

NOTE: Observed high test results for Task 3d, are the result of the incorporation of talc to the formula and reflects the relatively high specific gravity (2.8 g/cm³) of the material.

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